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Description

PIFA antenna arrangement for a plurality of mobile radio frequency bands

The invention relates to a PIFA antenna arrangement for at least two mobile radio frequency bands which are separated from one another, having a ground connection and an RF supply connection.

One such PIFA antenna arrangement is known, for example, from EP 0 997 974 A1, in which two planar antenna branches are provided, for each of which a common ground connection and a common RF supply connection are provided. The two antenna branches are connected in parallel with one another, and are intended for one resonant frequency in each case. The antenna branches have considerably extended antenna surfaces in each case, so that the PIFA antenna structure requires a large amount of space overall.

Against this background, the invention is based on the object of providing a PIFA antenna structure for a plurality of resonant frequency bands, and which is designed to be space-saving.

This object is achieved by a PIFA antenna arrangement for at least two mobile radio frequency bands, which are separated from one another, having a ground connection and an RF supply connection, in which the PIFA antenna arrangement has at least two antenna branches, which run parallel to one another essentially alongside one another, are in the form of strips and are connected to one another at a foot point in order to connect the antenna branches in series, the antenna branches run at a predetermined distance from one another in order to form a gap, the antenna branches have straight sections in

order to produce capacitive coupling between the antenna branches

the ground connection is arranged at a free end of one of the antenna branches, the RF supply connection is arranged at the outer edge of the antenna branch of the PIFA antenna structure, at which the ground connection is provided, and the widths of the antenna branches, the lengths of the antenna branches and the gap between the antenna branches are of such a size that the PIFA antenna structure has two resonant frequency bands with a desired separation from one another.

A structure such as this for a PIFA antenna arrangement allows a transmission characteristic and a reception characteristic to be produced for two different mobile radio frequency bands. The major parameters for setting the desired resonant frequency bands are the widths, the lengths and the width of a gap between the antenna branches. In detail, the ratio between the areas of the two antenna branches and the ratio between the widths of the two antenna branches corresponds, to a rough approximation, to the ratio between the two resonant frequency bands. The ratio between the positions of the two resonant frequency bands in a frequency spectrum can likewise be influenced by varying the width of the gap. Simple empirical investigations have made it possible for a person skilled in the art to optimize a PIFA antenna structure for specific application requirements by modification of the two ratios that have been mentioned, and the width of the gap, in which case it is possible to set not only the position of the two resonant frequency bands, but also their bandwidth.

The width of one antenna branch is preferably less than 1/15 of the wavelength of the higher-frequency frequency band. This has the advantage that the antenna branch is narrow, so that the overall volume of the antenna becomes smaller. Furthermore, there is stronger coupling between the antenna branches. In addition, the ratio between the first and the second resonant frequency can be changed more

easily. It is particularly preferable for the width of one antenna branch to be less than 1/20 of the wavelength of the higher-frequency frequency band.

The magnitude of the distance between the ground connection and the RF supply connection should preferably be matched to one of the resonant frequencies, specifically the higher resonant frequency, in order to define the higher-frequency frequency band. In most cases, there is a fixed ratio between the distance between the ground point and the RF supply connection and the (mid-) wavelength of the higher-frequency resonant frequency band.

In general, the two antenna branches run over essentially the same length to the foot point. However, it is also possible for one of the two antenna branches to have a length which differs from the length of the other antenna branch, for example by being greater or less than it. In this case, care should be taken to ensure that the inductive and capacitive coupling between the two antenna branches is in the desired orders of magnitude, which are important for the respective bandwidth of the resonant frequency bands.

It is likewise possible to provide for the predetermined distance between the two antenna branches not to be constant but to have a predetermined profile in the area in which the antenna branches run alongside one another.

It is also possible for the antenna branches which run alongside one another to have common bends, thus increasing the inductive coupling between the two antenna branches. A measure such as this can be adopted when the PIFA antenna structure has to be accommodated in a particularly space-saving manner, for example in the housing of a mobile telephone.

An extension to the PIFA antenna arrangement as explained above is formed by a PIFA antenna arrangement as claimed in one of claims 1 to 5, in which the PIFA antenna arrangement has two further antenna branches which run parallel to one another, alongside one another, at least in places, are in the form of strips and are connected to one another at a second foot point in order to connect the two further antenna branches in series with one another, the further antenna branches run at a predetermined distance from one another over one section in order to form a gap, the further antenna branches have straight sections in order to produce capacitive coupling between the antenna branches, the ground connection is arranged between the antenna branches and the further antenna branches, a further supply connection is arranged at the outer edge of the antenna branches of the PIFA antenna structure, at which the ground connection is provided, and the widths of the further antenna branches, the lengths of the further antenna branches and the gap between the further antenna branches are of such a size that the PIFA antenna structure has two further resonant frequency bands with the desired separation from one another.

The embodiment of the invention that has just been explained represents a combination of two essentially identical PIFA antenna arrangements with the structure explained initially. The extended PIFA antenna arrangement is thus able to receive and transmit in four different resonant frequency bands. To this extent, this embodiment of the invention provides a so-called "quad-band antenna structure", which is of particular interest at the moment for the development of antenna structures which can be used for standard international mobile radio frequency ranges (GSM850, EGSM900, PCN1800 and PCS1900).

It is preferable for the RF supply connection and the further RF supply connection to be arranged on opposite sides

of the ground connection, and to be joined together to form a common RF supply line.

The invention will be explained in more detail in the following text using exemplary embodiments and with reference to the drawings, in which:

Figure 1 shows a plan view of a PIFA antenna arrangement with two antenna branches, according to a first exemplary embodiment of the invention,

Figure 2 shows an equivalent circuit of the PIFA arrangement shown in figure 1,

Figure 3 shows a schematic illustration of a frequency spectrum of the PIFA arrangement shown in figure 1,

Figure 4 shows a plan view of a PIFA antenna arrangement according to a second exemplary embodiment of the invention,

Figure 5 shows a plan view of a PIFA antenna arrangement according to a third exemplary embodiment of the invention,

Figure 6 shows a plan view of a PIFA antenna arrangement according to a fourth exemplary embodiment of the invention,

Figure 7 shows a plan view of a PIFA antenna arrangement according to a fifth exemplary embodiment of the invention,

Figure 8 shows an illustration, in the form of a graph, of a simulation result for the frequency response of the

PIFA antenna arrangement shown in figure 1, optimized for the EGSM900 and Bluetooth frequency bands,

Figure 9 shows an illustration in the form of a graph of a simulation result for the frequency spectrum of the

PIFA antenna arrangement shown in figure 1, optimized for the EGSM900 and PCN1800 frequency bands,

Figure 10 shows a perspective view of a PIFA antenna arrangement according to a sixth exemplary embodiment of the invention, and

Figure 11 shows an illustration, in the form of a graph, of the frequency response of the PIFA antenna arrangement shown in figure 7.

Figure 1 illustrates a folded PIFA arrangement (F-PIFA) which is generally L-shaped for compactness reasons. The PIFA antenna arrangement has two antenna branches Z1, Z2, with the first antenna branch Z1 having a first width W1, and the second antenna branch Z2 having a second width W2. The two antenna branches Z1, Z2 are connected in series and are connected to one another at a foot point F. In addition, they run essentially parallel to one another, and alongside one another. The PIFA antenna arrangement shown in figure 1 is also characterized by the external dimensions of the antenna branch Z1, specifically a first length B1 between a free end and bend point K in the L shape, and a second length B2 between the bend point K and the foot point F.

A gap SP with a width T1, which remains essentially constant over the lengths of the antenna branches Z1, Z2, is defined between the two antenna branches Z1, Z2.

A ground connection G is provided at a free end FE of the first antenna branch Z1, to be precise at the outer edge of the first antenna branch Z1, facing away from the gap SP. An RF supply connection S for RF signals is provided on the first antenna branch Z1, at a distance from the ground point G. The

distance between the ground point G and the RF supply connection S is

optimized for one of two resonant frequencies of the PIFA antenna structure. The

PIFA antenna arrangement illustrated in Figure 1 is arranged at a distance H1 from a circuit board (not illustrated), on which contact is also made with the ground connection G and the RF supply connection S.

The following parameters are of particular importance for the ratio between the frequency of the first resonant frequency band and of a second resonant frequency band of the PIFA antenna structure: the ratio of the areas of the first antenna branch Z1 and of the second antenna branch Z2, the width T1 of the gap SP and the distance between the ground point G and the RF supply connection S. Primarily, the three parameters mentioned above must be matched for optimization of the PIFA antenna arrangement for a desired frequency spectrum with two resonant frequency bands, and this can be carried out by a person skilled in the art, by simple experiments.

Figure 2 shows an equivalent circuit of the PIFA antenna arrangement shown in Figure 1. The first antenna branch Z1 is represented in figure 2 by a first inductance L1, a first capacitance C1 and a first non-reactive resistance R1, while the second antenna branch Z2 is reproduced by a second inductance L2, a second capacitance C2 and a second non-reactive resistance R2. Coupling between the first antenna branch Z1 and the second antenna branch Z2 is represented by a third capacitance C3 and a third inductance L3. In this case, the magnitude of the third capacitance C3 depends primarily on straight sections of the two antenna branches Z1, Z2, running alongside one another, or else on the width T1 of the gap SP. In contrast, the inductive coupling between the two antenna branches Z1, Z2, which is represented by the third inductance L3, is governed by curved sections of the two antenna branches Z1, Z2, alongside one another. In the present exemplary embodiment, a first curved section occurs in the area of the

bend point, while a second curved section is provided by the foot point. The inductive coupling between the two antenna branches Z1, Z2 is particularly strongly pronounced in these two areas.

Furthermore, Figure 2 shows the ground connection G and the RF supply connection S. A signal between these two connections is coupled to the two antenna branches Z1, Z2 by means of a transformer.

Figure 3 shows a typical frequency spectrum for the PIFA antenna arrangement, as has been explained with reference to Figure 1. The frequency spectrum has two resonant frequency bands, which are annotated f1 and f2 in figure 3. The value of f1 is governed essentially by the distance between the ground connection G and the RF supply connection S. The precise position of the resonant frequency band for the frequency f2 depends on the ratio between the areas/widths W1, W2 of the two antenna branches Z1, Z2 and the width T1 of the gap SP. For given lengths B1, B2, the area ratio between the two antenna branches Z1, Z2 can thus be modified by variation of the width ratio W1/W2, in order to achieve a desired position for the second resonant frequency band for the frequency f2.

Figures 4 to 7 show three modified embodiments of the PIFA antenna arrangement shown in figure 1. In the embodiment which is illustrated in figure 4, the antenna branch Z2 has a reversal point at approximately the same level as the ground connection G. Two sections of the antenna branch Z2 are located essentially parallel to one another from this reversal point.

The difference between the PIFA antenna structure shown in Figure 1 and that shown in figure 5 is that the antenna branches Z1, Z2 are three-dimensional.

Beyond the RF supply connection S, the antenna branch Z1 has a cross section which is essentially right-angled. This also applies to the antenna branch Z2.

The embodiment shown in Figure 6 of a PIFA antenna arrangement is distinguished by the two antenna branches Z1, Z2 not being in the form of elongated elements, but by their width or general structure varying, starting from the foot point F. In particular, the width W1 of the first antenna branch Z1 as well as the width W2 of the second antenna branch Z2 vary, in each case from the foot point F to the opposite end of the relevant antenna branch Z1, Z2.

The further embodiment of a PIFA antenna arrangement as illustrated in Figure 7 is a generalized example in which case, in particular, the external shape of the PIFA antenna arrangement is comparatively irregular. As can be seen from figure 7, it is sufficient for the functionality of the PIFA antenna structure for the two antenna branches Z1, Z2 to run approximately alongside one another and parallel to one another. The respective overall lengths of the antenna branches Z1, Z2 may also differ from one another. In comparison to the PIFA antenna arrangement shown in Figure 1, the PIFA antenna arrangement shown in figure 7 has two curved areas for the two antenna branches Z1, Z2, thus increasing the inductive coupling between the two antenna branches Z1, Z2 in comparison to the PIFA antenna arrangement shown in figure 1. The PIFA antenna arrangement shown in figure 7 also has the foot point F, at which the first antenna branch Z1, which originates from the ground connection G, is connected to the second antenna branch Z2, in the form of a series circuit.

Two frequency spectra (reflection spectra) of PIFA antenna arrangements will be explained with reference to figures 8 and 9 in the following text, in the same way that they have been explained with reference to Figure 1.

The graphs in each case show the magnitude $|S_{11}|$ as a function of the frequency in MHz.

The major parameters of the PIFA antenna arrangement shown in figure 1 were chosen to be as follows in order to obtain the frequency spectrum shown in Figure 8:

W1 = W2 = T1 = 2 mm, B1 = 36 mm, B2 = 14 mm, H1 = 6 mm.

This means that the PIFA antenna structure has a volume of 1.58 cm^3, which means a very compact structure.

The choice of the parameters in the manner mentioned above results in the frequency spectrum shown in figure 8, which has pronounced resonant frequency bands both in the EGSM900 frequency range and in the Bluetooth frequency range. To this extent, the PIFA antenna structure is matched for transmission and reception of signals from the two standard mobile radio frequency ranges.

The frequency spectrum shown in Figure 9 is likewise based on a PIFA antenna arrangement of the type shown in figure 1. The relevant parameter magnitudes are as follows:

W1 = 4, W2 = T1 = 2 mm, B1 = 36 mm, B2 = 18 mm, H1 = 7 mm.

This results in an antenna volume of 2.94 cm^3, which is somewhat greater than that in the previous example. A PIFA antenna structure such as this has resonant frequency bands for the EGSM900 and PCN1800 standard mobile radio frequency ranges, as can be seen directly from Figure 9.

For illustrative purposes, Figures 8 and 9 show the positions of the relevant standard mobile radio frequency ranges separately in the form of a dashed-dotted line or dashed line.

A third exemplary embodiment of a PIFA antenna arrangement with an essentially rectangular outer edge is shown in figure 10. The PIFA antenna arrangement is designed to transmit and receive in a total of four different standard mobile radio frequency ranges. With regard to the designation of components and parameters for the PIFA antenna arrangement illustrated in Figure 10, the same reference symbols are used for components and parameters with the same effect as in figure 1.

Fundamentally, the PIFA antenna arrangement shown in Figure 10 corresponds to a combination of two PIFA antenna arrangements as shown in figure 1, with the ground connection G defining a junction point between the two PIFA antenna arrangements.

The PIFA antenna arrangement illustrated in figure 10 has two pairs of antenna branches, specifically a first pair Z1, Z2 and a second pair Z3, Z4. In this case, the antenna branches Z3, Z1 are connected to the ground connection G, with their "free ends" coinciding.

The third exemplary embodiment of the PIFA antenna structure has two foot points F1, F2, which are defined as follows: the two antenna branches Z1, Z2 together describe a general U-shape, whose free ends govern the positions of the foot points F1, F2. In this case, the width W1 of the antenna branches Z1, Z3 is the same. In alternative exemplary embodiments, these widths may also differ from one another.

The antenna branches Z2, Z4 are located in the interior of the general U-shape which is described by the antenna branches Z1, Z3. The antenna branch Z2 runs from the foot point F1 parallel to and alongside the antenna branch Z1, extends by a specific distance beyond the ground connection

G, and is bent back in the final section, so that the antenna branch Z2 is partially folded.

The antenna branch Z4 originates from the foot point F2, but first of all runs essentially at right angles to a straight section of the antenna branch Z3 that is adjacent to the foot point F2. As soon as the antenna branch Z4 has reached a predetermined distance from the opposite antenna branch Z2, it is folded back and runs alongside its initial straight section. As soon as the antenna branch Z4 has reached a predetermined distance, specifically the width T of a gap SP1 between the antenna branch Z3 and the antenna branch Z4, it runs alongside and parallel to the antenna branch Z3.

The antenna branches Z2, Z4 have the same width W2. In alternative embodiments, these widths of the antenna branches Z2, Z4 may also differ from one another. A PIFA antenna structure element formed by the antenna branches Z1, Z2 has a gap SP2 whose width corresponds to the width T. The gap widths between the two PIFA antenna structure elements may, of course, also be different. The widths of the respective gaps SP1 and SP2 are governed by sections of mutually associated antenna branches running alongside one another in parallel, such as Z3 and Z4, as well as Z1 and Z2.

The PIFA antenna structure shown in figure 10 has a common (not illustrated) RF excitation circuit, which is formed on a circuit board (not illustrated). The PIFA antenna structure is at a distance H1 from the circuit board and has two RF supply connections S1, S2, of which the supply connection S1 is associated with the antenna branch pair Z1, Z2, and the RF supply connection S2 is associated with the antenna branch pair Z3, Z4. The two RF supply connections S1, S2 are joined together to form a common RF supply

connection S, so that the same excitation signals are available for the PIFA antenna structure at the locations defined by the RF supply connections S1, S2.

With regard to capacitive and inductive coupling, the antenna branches Z1, Z2, Z3 and Z4 behave in a similar way to the antenna branches Z1, Z2 shown in figure 1.

Figure 11 shows a frequency spectrum of the PIFA antenna structure as shown in figure 10, with predetermined values for the major parameters. These values are chosen as follows:

$$W1 = 3\ \text{mm},\ W2 = 2\ \text{mm},\ T = 1\ \text{mm}.$$

The overall width of the PIFA antenna structure is 36 mm, and the overall length of the PIFA antenna structure is 24 mm. This results in an antenna volume of 6.0 cm^3. The distance H1 between the circuit board and the PIFA antenna structure is 7 mm. The spatial position of the four antenna branches (Z1, Z2, Z3 and Z4) is in each case evident from figure 10, which was discussed above.

As is evident from the frequency spectrum shown in figure 11, the PIFA antenna arrangement has resonant frequency bands for the GSM850, EGSM900, PCN1800 and PCS1900 standard mobile radio frequency ranges, thus providing a so-called "quad-band" antenna. The frequency spectrum shown in figure 11 is also a simulated spectrum.